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RESEARCH IN THE FIELD OF DEVELOPING NEW METAL POWDER MATERIALS IN THE USSR

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During recent years the scientific research organizations and the industrial enterprises of the USSR have been devoting a great deal of attention to the development of new metal powder materials and new technological processes in powder metallurgy. Research in this field first of all involves such problems as the development of materials of increased strength on an iron base for the manufacture of supporting parts of machines, the development of methods for obtaining materials for various purposes by rolling metal powders, the development of materials strengthened by disperse inclusions, of oxides, the development of methods for obtaining refractory compounds and using them to produce materials for various purposes, the development of new types of contact, anti-friction, filtering and other materials.

In the following we shall discuss the most interesting research in this field.

I. Strengthened Metal Powder Materials for Supporting Parts of Machines

As is known, the extensive use of parts pressed from iron powder is frequently restricted by the insufficient mechanical strength of pure powdered iron. The main trends in the endeavors to raise the strength of such materials are the alloying of iron with small additions of carbon, manganese and silicon, which are orginary additions in cast steels, as well as the raising of the strength by impregnating porous parts with molten metals or by sintering in the presence of the liquid phase.

In the manufacture of modern machines and instruments 60-65 per cent of all parts are manufactured of machine steels containing from 0.2 to 0.45 per cent of carbon. Hence, the development of a simple economical method of obtaining metal powder steel with this carbon content can solve the problem of the extensive use of parts made by pressing powders.

Such methods of alloying powderdd iron with carbon as introducing graphite into the initial charge or chemicothermal saturation during the sintering process do not secure material with good properties for two reasons: the non-uniform distribution of the carbon and the invariably low content in the iron of silicon and manganese, which is of great importance for the strengthening of the material during subsequent thermal treatment.

The problem of alloying iron with carbon, silicon and manganese is conveniently solved on employing mixtures of iron and cast iron powders. Attempts along these lines have been undertaken by G. Will, M.Y.Balshin, A.S.Fedorishchenko[1,2,3] but no positive results were attained, owing to the fact that the iron powder was mixed with a grey cast iron powder obtained by breaking up shavings which contained as much as 2-3 per cent of free carbon. The latter is readily exfoliated in the process of mixing, readily burns out during sintering and does not give a uniform structure and stable properties.

I.D.Radomyselsky and M.A.Kuzenkova[4] successfully employed powder of chilled cast iron, in which all the carbon was in a bound state, as a result of which no finely dispersed free graphite was formed during grinding. The white cast iron powder was obtained by grinding in an eddy mill or in a mechanical mortar wastes of chilled cast iron plates manufactured by a number of enterprises in the USSR. Owing to the great brittleness of white cast iron plates, there was no difficulty about grinding the material into a powder.

A cast iron powder of the following composition was employed in the investigations: C_{total} - 3.2 - 3.4 p.c., C_{free} - 0.5 pc., Mn - 0.5-0.4 p.c., Si - 1.4 - 1.8 pc., P - up to 1 p.c., S - up to 0.1 p.c.

The effect of granularity was studied on two bmands of powder: brand A had 67 p.c. of the particles less than 0.15 mm and 33 p.c. over 0.15 mm in size; brand B had about 95 p.c. of the particles less than 0.15 and about 5 p.c. over 0.15 mm in size.

Some 15 to 20 p.c. of cast iron powder was added to the iron powder prepared by the method of reducing scale powder by natural gas. The iron powder had the following chemical composition: C - 0.08 p.c., Mn - 0.5 p.c., Si - 0. p.c., S - 0.02 p.c., P - 0.02 p.c.

As a result of investigations of the modes of pressing and sintering the following process was developed for manufacturing machine parts: preparation of a mixture of iron powder with 20-30 p.c. of cast iron powder, first pressing at a pressure of 4-6 t/cm^2, first sintering at 650°C, second pressing at a pressure of 8-9 t/cm^2, second sintering at 1200°C in hydrogen or converted natural gas in the course of 2-3 hr.

Such a mode of manufacture secured parts with a density of 7.0 - 7.2 g/cc (porosity 7.5 - 10.5%). The necessity of the first sintering at 650°C arose from the considerable increase inthe dimensions of the parts (up to 4-5% in length) on sintering at higher temperatures.

The physical and mechanical properties of the materials produced by the developed process are presented in Table I.

The highest strength and hardness is possessed by samples made of a mixture containing 30% of brand A cast iron powder (the coarser brand). This material has a tensile strength of 42-44 kg/mm^2 and a Brinell hardness after normalizing of 207-214 kg/mm^2 with an elongation of 1.3-1.4%. The structure of the material after sintering consists principally of pearlite with a small number of ferrite inclusions. After quenching from 840°C in water the material has a hardness of 47-54 units R_c.

The results of the research show the possibility of manufacturing from a mixture of iron powder and white cast iron powder structural material with a sufficiently high strength and hardness having a low viscosity.

The introduction of up to 30% of white cast iron powder into the alloy permits obtaining a steel structure by a sufficiently simple and industrially practicable method; it also secures a saving of 30% of iron powder, which is three times as expensive as cast iron powder.

A further increase in the strength of powder structural material may be attained by impregnating a porous framework made of iron powder with molten metal. Most of the researches along these lines deal with iron-copper compositions. The problems of strengthening iron by impregnating with molten copper and by introducing a certain quantity of copper into the initial charge have been studied. It was established that compositions of this kind can possess good mechanical properties, comparable with those of structural steels.

The question of alloying iron with brass [5,6,7] has been studied to a lesser extent, though such compositions are also of practical interest. It is possible to use industrial waste material such as shavings of brass and other copper alloys in such compositions.

O.K.Teodorovich and I.D.Radomyselsky [8] studied the properties of iron-brass compositions with various contents of brass and carbon, obtained by the method of impregnating an iron porous briquette with liquid brass.

The process of manufacturing parts consisted of the following operations: a) pressing parts, from iron powder or from iron powder with a graphite addition, having dimensions and shapes corresponding to the finished parts. The porosity of the briquettes is regulated in accordance with the content of the impregnating metal in the finished material; (b) sintering of briquettes at 1100-1150°C in a reducing atmosphere during three hr; (c) pressing the briquette from brass shavings; (d) impregnating the porous framework with molten brass, for which purpose the porous framework and the brass briquette are placed one on the other and in a filler of refractory clay are heated in a furnace up to 1000°C.

In the investigation use was made of brass containing 40% Zn, 58% Cu, 1.4% Pb, the rest comprising iron and other impurities. An iron powder was employed which was obtained by the method of reducing scale with natural converted gas. The chemical composition of the iron powder was Fe- 98.8%, Mn - 0.33%, Si - 0.01%,

Table II presents the properties of the material depending on the carbon content and the mode of thermal treatment with an optimal brass content of 20%. As seen from the table, iron-brass impregnated compositions possess good sgrength properties.

The basic strengthening factors in such kind of materials are the solution of copper in iron at a high temperature, its strengthening action during subsequent isolation from the saturated solid solution in the form of disperse inclusions, and the elimination of the weakening action of pores, since the latter are filled with the impregnating metal.

In the research of I.N.Frantsevich and O.K.Teodorovich [9] it was also established that the most favorable combination of the properties of strength and plasticity in iron-copper compositions is attained on employing previously alloyed initial materials: iron powder with 5-8% Cu and a brass or Cu component with up to 5% iron. At the impregnation temperature these quantities of the alloying admixtures secure saturated solid solutions of the composition elements hence there is no effect of solution and pickling of the iron framework by the liquid metal and no diffusion of elements from the iron component into the copper or vice versa. This fact excludes the appearance of diffusive porosity on the grain boundaries which has a very deteriorating effect on the mechanical properties of the material.

An electron microscopic investigation showed that in alloys obtained from pure unalloyed initial powders the grain boundaries have numerous defects of the submieroscopic crack type. In alloys on a base of interbalanced phases there are more perfect grain boundaries without defects.

This difference affects the mechanical properties of alloys. In the first case the properties of plasticity are lower by almost one-half, and the fatigue strength of the material is considerably lower.

The developed technology of manufacturing iron-brass impregnated compositions permits obtaining sufficiently high mechanical properties of the material, which can satisfy the strength requirements of most of the parts used in machine and instrument manufacture.

II. Materials Obtained by Rolling Powders

Research in the field of rolling metal powders in the USSR has recently been conducted chiefly along the following lines - the developmeng of improved rolling equipment, the study of the mechanism of rolling and the study of the properties of various kinds of rolled materials designed for industrial use.

The technology of rolling sheet materials from iron, nicke, and copper powders has been fairly well studied. The completion of the research on the rolling of powders was the development by G.A.Vinogradov and I.M.Fedorchenko [10], aided by designing organizations, of an experimental mill which can be used for both research and industrial purposes.

The mill consists of a roughing stand (Fig. 1), two finishing stands (Figs. 2, 3) and reelers. The drive for each stand is effected by a direct current motor through a worm reducing gear, a gear cage and two universal spindles. The drive of the reelers is effected by a direct current motor through a worm reducing gear and a chain transmission.

The pressing device of the rogghing and the finishing stands is manual and dual, the precision of adjusting the gap between rollers being 0.05 mm by the dial. All units may operate simultaneously or separately in any combination. On all stands the rate of rotation of the rollers can be regulated without steps within limits of 1 to 8 rpm and by steps, up to 15 rpm.

The roughing and the first finishing stands permit rolling a metal ribbon from powder and slabs in an air and protective medium (argon, helium, etc.) for which purpose the rollers have a hermetic sealing hood.

The design of the roughing and the first finishing stands permit setting them up in a horizontal and a vertical position.

The first finishing stand has an attachment whereby the gap between the rollers may be increased or decreased during rolling at each revolution of the roller by a value of 0.2, 0.3, 0.4, 0.5 and 0.6 mm. Furthermore, hydraulic capsules can be placed under the pads of the lower roller to measure the pressure during the rolling process.

The motors for each stand have a power of 11 kw.

The stands have the following roller dimensions: the roughing stand has replaceable rollers with diameters of 150, 250, and 300 mm with a barrel length of 250 and 350 mm. The first finishing stand has rollers with a barrel length of 250 mm; the second 200 mm.

The following work may be carried out on the roughing and the first finishing stands:

a) vertical cold rolling of powder in air and protective media;

b) horizontal cold rolling of powder and slabs;

c) horizontal hot rolling of slabs in a protective gas medium.

The second finishing stand is designed chiefly for the cold densifying rolling and the manufacture of poreless ribbons and plates.

The first and the second finishing stands have an attachment for using them as drawing drums during wire drawing.

The described rolling mill can produce rolled metal from 0.2 to 2.0 mm in thickness.

From the standpoint of an understanding of the mechanism of the processes occurring during the rolling of metal powders and the extension of the possibilities of solving practical problems, it is interesting to review the results of our investigations [11], [12] of the effect of the gaseous phase on powder pressing during rolling.

It was found, in agreement with the available data in the literature, that the viscosity of the gases contained in the pores between powder particles i san important factor, which should be taken into consideration along with other factors affecting the thickness and density of a ribbon rolled fmm powder.

The air contained in the vacancies between particles, onbeing squeezed out during rolling, sets up a counter-current mechanically retarding the flow of powder into the focus of deformation between the rollers. Special experiments have shown that if the rate of rolling is greatly reduced so as to secure a quiet elimination of air, the thickness of the resulting ribbon greatly increases under invariable conditions of rolling. Thus, on rolling iron powder between rollers with a diameter of 85 mm in an air medium at a rate of rolling of 0.355 m per sec., with the rollers adjusted to a gap of 0.160 mm, a ribbon is obtained having a thickness of 0.253 mm and a density of 4.33 g/cc. On reducing the rate of rolling to 0.0089 m per sec under the same conditions, a ribbon was obtained having a thickness of 0.427 mm and a density of 5.18 g/cc. The unfavorable effect of the air is fully eliminated when rolling is conducted in a vacuum with a rarefaction of 10^{-1} mm Hg. On rolling on the same rollers in a vacuum chamber at a rate of rolling of 0. 355 m per sec, a ribbon was obtained with a thickness of 0.407 mm and a density of 5.05 g/cc. The unfavorable effect of the air in the vacancies between particles is particularly evident in the case of the rolling of fine powders. Iron powder with a particle size of less than 44 micron in an air medium could not be rolled into a ribbon on the same rollers. On rolling in a vacuum, even with a low rarefaction (150 mm Hg) it was rolled into a ribbon 0.54 mm thick. With a rarefaction of 1 mm Hg a strong flexible ribbon, 0.70 mm in thickness was obtained.

Vacuumizing the rolling process doesnot only result in the elimination of the countercurrent of air, but also in a rise in the coefficient of friction among the powder particles and between the particles and the roller surface, owing to the removal of adsorbed gases. As a result the drawing of powder into the deformation zone between the rollers is facilitated. Besides vacuumization, an increase in ribbon thickness and a rise in the efficiency of the rolling mill may be attained by feeding hydrogen or carbonic acid into the bunker with a powder, having a lower viscosity than air.

In the production of poreless strips by the method of rolling powders various technological processes may be used, including several successive operations of rolling and annealing.

The choice of the most economical process is of importance for production.

To solve this problem it is necessary to determine what should be the density of the raw ribbons after the first rolling, the mode of sintering to be employed after rolling, and the degree of compression most advantageous for obtaining a ribbon with maximum density.

Our investigations [13] on iron powder obtained by the method of reducing scale by natural converted gas have given the following results (the rolling was carried out on a two-roller mill with a roller diameter of 186 mm, width of ribbon 160 mm, thickness 1.0-1.3 mm).

To obtain an iron poreless strip by the rolling method the initial strip should have a porosity of 20-25% after the first rolling. With a lower porosity the ribbon become tough, brittle and cannot be wound into a roll. Material with higher porosity has insufficient mechanical strength.

An investigation of mechanical properties conducted on rolled ribbons having a porosity of 25%, sintered at temps. of 900, 1000 and 1100° and various durations up to 30 min., showed that to secure the possibility of a continuous technological cycle the most rational duration of sintering equals 10 min. Fig. 4 shows the change in the tensile strength depending on the duration of sintering. A duration of 10 min. secures 60-80% of the strength obtained on sintering for 30 min. Such a strength level is sufficient to ensure normal behavior of the strip during the subsequent densifying rolling in cold.

In addition it was established that the mode of preliminary sintering of the ribbon in a temp. range of 750-1200°C has a slight effect on its behavior during the subsequent rolling and on the final mechanical properties. The ribbons easily endure a densifying compression up to 40%.

The effect of the mode of preliminary sintering of the ribbon on the final mechanical properties is shown in Table III.

The results presented in the table were obtained on ribbons having a porosity of 25% in their initial state; after preliminary sintering under the conditions indicated in the table they were compressed in one pass by 28.5% in height; then they were annealed in hydrogen at 750° for 1 hr; they were again rolled in cold in one pass by 37.5%, and finally annealed in hydrogen at 750° for 1 hr.

As seen from the table the ribbon has high indices of strength and plasticity. The somewhat lower plasticity of the ribbon sintered during 1 min is apparently accounted for by the incomplete reduction of the oxides during the preliminary sintering.

Investigations have also established that with an initial porosity of the ribbon of 20-25%, it is expedient to apply compression of about 30-35% for the final densification of the ribbon.

Fig. 5 shows the dependence of the physical and mechanical properties on the degree of densification in cold for ribbons havin g an initial porosity of 25% and subjected to sintering under various conditions. As the degree of compression increases there is an increase in density up to the max. during compression by 37-40% being somewhat lower than a density of 100%. Further increase in compression does not result in densification, since there appear such factors as a rise in the number of dislocations, an increase in elastic stresses, and loosening of the structure. The latter is corroborated by the beginning of a decrease in the ultimate bending strength on reaching a degree of compression of 40-45%.

At the same time the microhardness and coercive force continue to increase, owing to the increase in the degree of deformation in microvolumes.

These data permit recommending the following technological process for manufacturing poreless iron ribbons by rolling powder: the rolling of the slab to give a porosity of 20-25%, sintering at 700-750°, densifying rolling in cold with compression by 27-30%, annealing and a second rolling with compression by 25-35%.

Poreless iron sheets obtained by rolling powder are of considerable practical interest from the standpoint of their use as magnetic-soft material in various parts for electrical engineering purposes.

The following requirements have been set for such materials by the Soviet bureau of standards: coercive force H_c = 0.8 - 1.2 oerst, max. magnetic permeability μ_{max} = 3500-4500 gauss/oerst. The author together with O.A.Kartus and G.A.Vinogradov conducted investigations on estimating the possibility of obtaining rolled iron plate which meets these requirements and studying the factors affecting the coercive force and the magnetic permeability of the material.

The results obtained concerning the effect of grain size on the coercive force of poreless iron sheet are shown graphically in Fig. 6. To obtain sheets with different grain size, ribbons preliminarily sintered and rolled with intermediate annealing were heated at different temps. ranging from 700-1200° with a duration of 2 hr. As seen from the graph, an increase in grain size from 450 micron^2 to 41000 micron^2 results in lowering the coercive force by 0.5 oerst.

The effect of the annealing temp. on the coercive force and the initial magnetic permeability is shown in Fig. 7.

A great effect on the magnetic characteristics of iron powder plates is exerted by porosity. This dependence is shown in Fig. 8 within a range of 0-25% porosity. This rectilinear dependence indicates that each 2 % of pores increases the coercive force by 0.1 oerst. The investigations were conducted on iron powder obtained by reducing scale by natural converted gas.

It was established in this investigation that with a preliminary sintering of a ribbon with a porosity of 25% in hydrogen with a dewpoint of -30°C at 1200°C, the material is refined in respect to oxygen and carbon, the content of which drops to 0.02-0.03%.

With a proper choice of sintering conditions and taking into account the effect of additions, grain dimensions and residual porosity, we may rely on securing sheet material, obtained by rolling iron powder under industrial conditions, which possesses magnetic characteristics meeting the requirements of the electrical engineering industry.

Y.N.Semenyonov[12)] made a detailed study of the process of rolling carbonyl nickel powder. He developed a technological process of rolling which secures poreless ribbons with an ultimate tensile strength of about 40 kg/mm^2 and an unit elongation of 36-44%. A nickel ribbon of carbonyl powder was tested on cathodes of electrovacuum instruments and recommended for use in the radio-engineering industry. Poreless titanium ribbon was also obtained by rolling. This ribbon has ultimate strength of 60 kg/mm^2 and/unit elongation of 25%.

Investigations on obtaining poreless titanium ribbon were conducted by V.G.Khromov and N.P.Gromov and Bakulin[12)]. V.G.Khromov suggested the following technological scheme for obtaining a thin titanium ribbon by rolling powder: rolling a ribbon 0.65 mm in thickness with a density of 3.5 g/cc; sintering at 850°C during 1 hr; cold rolling with 40% compression; annealing at 900°C for 1 hr; rolling to a thickness of 0.23 mm; annealing at 85-°C for 0.5 hr. The annealing or sintering was carried out in high vacuum (10^{-4} - 10^{-5}mm Hg) or in carefully purified argon or helium. A ribbon made of titanium powder by the calcium thermal method had an ultimate strength of 60 kg/mm^2 and a unit elongation of 25%.

III. Metals Strengthened by Disperse Inclusions of Oxides

A great deal of attention has recently been devoted to the development of materials of the SAP type, constituting metals strengthened by very fine inclusions of oxides or another solid phase.

Of researches conducted in this field an interesting investigation is that of Y.N.Semyonov, G.S.Shmakov and Z.A.Yablokov [14) on the development of the technology of manufacturing and the study of the properties of a copper aluminum oxide alloy. To secure uniform distribution of highly disperse inclusions of aluminum oxide a new method proposed by Y.N.Semyonov was employed; involving the hydrolysis of aluminum trichloride on the powder particles. Ground copper scale and an aqueous solution of aluminum trichloride were mixed in the required propertions. After air drying the charge was reduced in an atmosphere of moist dissociated ammonia, the reduction being complete at a temperature of 700°C. The resulting sponge was readily ground into powder in an eddy mill. The powder was pressed into briquettes with a density fm of 70-79%; which were sintered at 800°C fot 2 hr and pressed at a specific pressure of 10 t/cm^2 (density 85-90%). To raise plasticity and eliminate porosity, the briquettes, heated to 1000°C were squeezed through the orifice of a mattix.

Table IV shows the change in hardness and electric conductivity of the resulting alloy, depending on the aluminum oxide content. The strength of the copper is substantially raised, the conductivity falling somewhat at the same time.

The inveseigated alloy showed a considerable rise in heat resistance. Fig. 9 shows the dependence of the hardness of the alloy on the annealing temperature. With an aluminum oxide content of 3.5% the hardness begins to decrease only after heating to 500-600°C.

These properties of the alloy make it suitable for manufacturing parts of devices where heat and electro-erosion resistance are required with relatively high electric donductivity. The use of a Cu-Al oxide alloy for the manufacture of welding machine electrodes showed an increase in the durability of the electrodes 2-3 times as great as in copper electrodes.

The electrode instruments of electric spark devices for metal processing, made of Cu-Al oxide alloys, showed a durability which was give times as high as that of the brass electrode instruments widely used in plants.

IV. Refractory Compounds and Materials Made with Them as a Base

A great deal of attention has recently been paid to working out methods for the manufacture of various types of refractory materials and to studies of their properties. To satify the needs of the developkng new techniques, it is essential to have materials possessing - along with great hardness, durability, strength, refractoriness - a number of special physical properties as well, such as high or low conductivity, the capacity for passing into a superconductive state at relatively high temps, semiconducting and other properties.

Among the more promising materials of this type are hard and refractory metal-like compounds of rare and rare-earth metals (Ti, Zr, Hf, V, Nb, Ta, Mo, W, La Ce, Yt) with boronm carbon, silicon, nitrogen and sulfur - the so-called borides, carbides, silicides, nitrides and sulfides.

The investigation of the properties of these materials and the development of methods for the manufacture of various kinds of parts have resulted in the discovery of new fields of their application in engineering.

D.V.Samsonov and P.S.Kisly [15] developed a method of manufacturing thermocouples for high temp. measurements from materials on a base of refractory compounds. The investigations of the temp. dependence of the thermal electromotive force of refractory comápounds showed that many of them possess fine characteristics of thermal electromotive force, which adapt them for the manufacture of thermocouples designed for work at high temps. Fig. 10 showe the graph of the dependence of the thermal electromotive force of boridized graphite electrodes with metal-like refractory compounds.

The highest thermal electromotive force is attained in systems of Ti and Zr borides with BC, the temperature dependence becoming linear beginning with 300°C.

Most of these compounds possess high resistance to the action of aggressive media, which makes these materials indispensable for the manufacture of thermocouples designed for measuring temps. of molten metals, slags, salts, as well as of incandescent gases.

Fig. 11 shows the diagram of a thermocouple made of BC and $MoSi_2$ for measuring temp. up to 1700°C when working in air, in many reducing media, as well as in certain molten metals. The inner core is made of boridized graphite; the outer case, of $MoSi_2$.

This thermocouple has en electromotive force three times higher than that of one made of platinum and platinorhodium, and gives readings which are just as stable.

Tests of the thermocouple on the measurement of the temps. of open hearth waste gases showed that it could give accurate readings during continuous work in the course of 20 hr in a gas stream with a temp. of 1800-1900°C.

A test of thermocouples with a ZrB case on cast iron tapping from blast furnaces showed that they have high resistance and stability of readings. Such thermocouples can work several hrs. in molten steel at 1700°C.

In various set-ups in radio engineering, automatics and electrical engineering it is necessary to employ volume resistors with high stability in work with a wide range of given values of electric resistance. G.V.Samsonov[16)] developed volume resistors with a conducting composition of chromium boride and TiC. Their moistening coefficient after they have been kept in a chamber with a relative humidity of 98% at 40°C for 400 hr is only ± 2%. The aging coefficient after 100 hr of electric load (of 1.5 P_H) equals ± 2.5% while the temp. coefficient over a range of 20-155?°C is $5-6.10^{-4}$°. High ohmic volume resistors (10^2 - 10^4 ohm. cm) with current conducting elements of aluminum bromide have a low thermal coefficient of resistance and are practically characterized by the latter being independent of the temp.

The possibilities of developing high ohmic resistors using refractory compounds with a wide variation of their characteristics are practically unlimited.

An important element of every electronic device consists of cathodes. Cathodes, especially those of powerful electronic devices, are required to possess stability in operation, durability, wide ranges of power and the capacity of operating under insufficient vacuum conditions. These requirements are met by cathodes made of borides of the rare earth metals. The cathodes developed by G.V.Samsonov[16)] from lanthanum boride for work on the synchro-phasetron at high field tensions (up to 10^5 v/cm) and a working temp. of 1650°C permitted taking a current density up to 70 a/cm^2. On selecting a current of 40 a/cm^2 the life of such a cathode is about 250 hr. Fig. 12 shows various forms of cathodes made of lanthanum boride.

Boride cathodes of amplifiers of the magnetron type work well at a current density of 5 a/cm^2, a field tension of 100 v/cm and a working temp. of 1500°C.

A cathode made of lanthanum boride works 90-100 hr in the ionic source of a cyclotron instead of 10-25 hr as in the case of Ta cathode.

Refractory compounds find an ever-growing application in modern techniques for machining by grinding, drawing and curting various hard materials, steels and alloys.

Boron cabide may be very effectively applied instead of diamonds for grinding hard materials. G.V.Samsonov[16)] has developed methods for manufacturing and has tested so-called "pencils" and rings instead of diamonds for setting grinding wheels. The experience of engineering plants in the use of such pencils shows that their efficiency and durability, with a high finish of machining which does not yield to that obtained by diamond tools, is 5-6 times higher than other diamond substitutes. A test of drills 0.5 - 1.0 mm in diam. and 4-14 mm long, made of BC and some other hard compounds, showed high efficiency in machining watch and instrument jewels of agate, ruby and leucosapphire, being 60-70% of the efficiency of diamond drills.

V.V.Grigordea and V.N.Klimenko [17] developed nozzles on the base of an alloy of CrC with Ni for sandblasting apparatus. Working tests showdd that these nozzles are 15-20 times more durable thanthose made of hardened tool steel. Dies made of CrC alloy for the cold drawing of steel pipes showed a durability in operation of over 100,000 drawings, instead of the 4000-4500 for dies of hardened carbon steel

A no less valuable property of refractory compounds is their high resistance to the action of chemicals. Investigations have shown that the carbides of Ti, Zr, Ta and Nb are resistant for a long time in cold and boiling solutins of alkalis, muriatic, sulfuric, phosphoric (only in cold solutions) and chloric acids.

A particularly high resistance to the action of acids, alkalis and organic solvents ~~sx~~ is displayed by CrC [17].

A very high resistance to chemicals is also revealed by the borides and nitrides of refractory metals.

Parts made of refractory compounds and their alloys may be used as chemical vessels, crucibles, structural elements for pumps pumping cold and heated acid liquids, for refrigerators, nozzles for sprinkling active chemical liquids, for mixers resistant to corrosion with the simultaneous abrasive action of hard constituents of pulps or suspensions, etc. [18]

Fig. 13 shows crucibles made of carbides, borides and nitrides using the technology developed by G.V.Samsonov [17] and coworkers.

~~Rigxxi8xxkm~~

The use of refractory compounds for creating various kinds of heat-resistant alloys is also very promising. The structure of these compounds, their physical and chemical properties make them ideal components for the creation of an extensive range of materials meeting the diversified requirements of the developing new techniques.

Table I

PHYSICAL AND MECHANICAL PROPERTIES OF MATERIAL MADE OF MIXTURES OF IRON AND CAST IRON POWDERS SINTERED AT 1200°C FOR 3 HR IN HYDROGEN

Properties	Dimensions	Granulometric composition and content of cast iron powder in charge		
		A_1 20%	A_1 30%	B_1 20 %
Density	g/cc	7.1 - 7.2	7.0 - 7.1	7.1 - 7.2
Porosity	p.c.	9.5 - 7.5	10.5 -8.5	9.5 - 7.5
Carbon content	p.c.	0.35-0.42	0.50-0.55	0.35-0.40
Hardness	kg/mm^2	187 -229	207 - 241	162 - 187
Tensile str.	kg/mm^2	38.0-46.3	42.6-44.4	34.9-38.0
Unit elong.	p.c.	1.4 - 1.5	1.3 - 1.4	3.6 - 4.4
Resilience	kg/mm^2	2.2 - 3.1	-	1.8 - 2.2
Bending str.	kg/mm^2	79.0-83.6	-	73.2 - 78.0
Shearing str.	kg/mm^2	41.6 - 48.6	-	40.3 - 47.6
Compress. str.	kg/mm^2	110 -139	124.0-151.0	-

TABLE II

MECHANICAL PROPERTIES OF IRON BRASS COMPOSITIONS DEPENDING ON THE CARBON CONTENT AND THERMAL TREATMENT° BRASS CONTENT - 20%

Brand of material	Carbon content %	Specific gravity g/cc	Tensile strength kg/mm^2	Yield strength kg/mm^2	Elong. %	Contraction %
1) Immediately after impregnation						
1	0.07	7.79	38.5	25.9	8.4	20.8
2	0.07	8.0	51.5	40.5	4.7	12.6
3	0.15	8.0	51.2	40.0	7.9	25.0
4	0.20	7.93	50.0	44.2	9.0	32.0
5	0.93	7.58	64.3	-	0.5	2.0
2) After quenching from 850°C in water and tempering at 400-420°C						
1	0.7	7.79	64.2	55.8	2.0	5.2
2	0.07	8.0	74.2	62.0	2.0	4.2
3	0.15	8.0	67.3	-	7.0	10.1
4	0.20	7.93	67.8	82.0	8.0	12.0
5	0.93	7.58	89.0	-	2.0	0.95

TABLE III

EFFECT OF THE PRELIMINARY SINTERING CONDITIONS ON THE FINAL MECHANICAL PROPERTIES OF PORELESS RIBBONS

No.	Mode of preliminary sintering before densifying rolling	Final density, %	Final mechanical properties Tensile Str. kg/mm^2	Elong. %
1	750°, 11 hr	100	27.3	33.7
2	900°, 1 min.	99.9	29.6	22.7
3	1200°, 4 hr	99.8	26.16	36.6